SILVA BALCANICA

Silva Balcanica 25(3): 61-83 (2024)
doi: 10.3897/silvabalcanica.25.e132419

RESEARCH ARTICLE

Influence of the afforestation measures in the restoration of forest ecosystems after a fire on the territory of the Territorial Division of State Forestry "Botevgrad"

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Academic editor: Alexander Delkov | Received 18 July 2024 | Accepted 18 September 2024 | Published 24 October 2024

Citation: Stoyanov T., Grozeva M. 2024. Influence of the afforestation measures in the restoration of forest ecosystems after a fire on the territory of the Territorial Division of State Forestry "Botevgrad". Silva Balcanica 25(3): 61-83. https://doi.org/10.3897/silvabalcanica.25.e132419

Abstract

The purpose of the study is to determine the impact of afforestation measures on the main characteristics of soils, forest litter and grass cover in forest ecosystems after a fire on the territory of the Territorial Division of State Forestry (TD of SF) "Botevgrad" for different recovery periods. Four experimental Objects and four Control variants are selected, spread over brown forest (Cambisols), gray forest (Gray Luvisols) and pseudopodzolic (Planosols) soils to consider the changes that occurred after afforestation. A tendency was confirmed that forest fires lead to an increase in the susceptibility of soils to erosion due to the redistribution of the fractions of the mechanical composition, and to the increase in the amount of sand fraction. Changes in soil acidity have a neutralizing effect on fires, compared to the control option in pseudopodzolic (Planosols) soils. With a longer recovery period after a fire (over 20 years), due to a relative equilibrium reached in the soil, carbon stabilization is observed in brown forest soils (Cambisols), because of its sorption on clay minerals. The predominant part of the soils has a low degree of nitrogen enrichment at C: N>20. Austrian pine crops were found to be characterized by a greater supply of combustible materials in the forest litter. Post-fire period, slope and exposure of the slope, where the Objects are located, determine differences in grass cover mass and stock.

Keywords

Forest fires, plantation, mechanical composition, carbon, total nitrogen, pH.

Introduction

Forest fires are among the most dangerous natural risks in forests due to their extremely severe ecological, economic, social and demographic consequences. The destructive nature of forest fires manifests in the destruction of wood biomass, the organic and mineral part of soils, and deterioration of the water-physical properties of the soil, air pollution, causing erosion and increasing water runoff. After the fires, if measures are not taken to regenerate the vegetation quickly through afforestation, significant erosion processes, losses of organic matter and soil degradation occur. In terms of soil erosion and biodiversity, fire damage is difficult and often practically irreversible.

Forest fires contribute to climate change because they cause the rapid release of large amounts of CO_2 and other greenhouse gasses into the atmosphere (Levine, 1996; CCSP, 2008). Because of climate change, characterized by increasingly warmer and drier summers, the risk of fires has grown significantly over the past 20 years. In addition to fires typical for Mediterranean forests, boreal (northern coniferous) forests, which are characterized by higher humidity, have already been significantly affected as well.

Studying the impact of fires on reforestation is the subject of many authors. Tsakov et al. (2020) note that after burning the organic matter of the soil litter, the mineral structures under the surface layer change their physical and chemical properties, harden, and are poorly permeable to water and air. The authors found that the biological diversity in the upper forest vegetation zone of Northern Pirin, was disturbed because of a fire, the tree and grass vegetation destroyed, and the hydrological effect of the forests was reduced. They also note that deciduous vegetation has naturally settled in the damaged highland part of the Rila National Park, which, together with the burnt dwarf mountain pine (*Pinus mugo* Turra) stems, will have a snow retention, anti-avalanche and hydrological effect.

Ilyichev et al. (2003) wrote that after a fire, soil porosity reduction and normal natural regeneration are hampered. Sapozhnikov, A.P. (1979) noted that complete destruction of the tree floor, grass cover, and forest litter by fire resulted in an increase in stand light. Furyaev, B.B. (1973) found that after a fire, more precipitation penetrates the plantations, and the temperature regime of the soil and the surface layer of the air in the ecosystems are changed. Kolesnikov, B.P. (1973) and Sapozhnikov, A.P. (1976) noted that a redistribution of surface and subsurface runoff occurs in forest stands after fire. Molchanov, A.A. (1973) also conducts studies to determine the impact of fires on the processes of subsequent afforestation, due to the significant changes in the environmental conditions in the burned areas. Furyaev B.B. (1996) analyzed the complex ecological conditions in the restoration of forest plantations and found that, under extreme natural and climatic conditions, this issue is relevant and has subsequent practical results. Therefore, research on the restoration of forest ecosystems after a fire has not only scientific, but also practical importance for solving the complex problems that have arisen after it.

Forest fires affect soil properties, thereby affecting the composition and structure of the vegetation in their wake (Neary et al., 1999; Jain et al., 2008). The degree of change in soils depends on the strength of the fire, the degree and depth in the soil to which the heat

released during combustion is transmitted and the type of soil (Neary et al., 2005). Fires can also cause the formation of a water-impermeable layer, which reduces the infiltration of water into the soil, increases surface runoff and leads to an increase in the intensity of erosion processes (Velizarova, 2014b), as well as to changes in the biochemical cycle of soils through loss of humus, increase of pH or the amounts of nutrients in soils.

Topalova et al. (2005), Velizarova et al. (2006), Filcheva et al. (2011), Velizarova et al. (2014a), Ilinkin et al. (2013), and Velizarova et al. (2017) have carried out studies on changes in soil characteristics after a fire. They investigated the carbon content in forest fire-affected soils under different tree species from the region of South-Eastern Bulgaria. Ilinkin et al. (2013) tracked changes in total carbon content in gray forest soils (Gray Luvisols). Zhiyanski (2014) notes that among the factors that can influence soil carbon sequestration, fires occupy a special place. Bogdanov et al. (2015) investigated changes in total carbon content in degraded soils. They concluded that after a fire, the total carbon content of the examined cinnamon forest soils (Chromic Cambisols) increased. The amplitude and duration of the fire corresponds to the dynamics and strength of the fire, which gives the authors reason to accept the total carbon content as a reliable indicator characterizing the degree of influence of forest fires on the changed properties of the affected soils. Subsequent afforestation, tailored to the specific conditions and biological characteristics of the species, will allow the formation of sustainable forest ecosystems in the burned areas.

To predict forest fires, it is important to clarify the factors that cause them. Among them, the geographical and climatic features of the region, the topography and the plant cover are of decisive importance. According to Andrews, Queen (2001), the combination of these factors with the characteristics of the combustible material (a physical characteristic of the biomass that facilitates the spread, intensity and strength of a forest fire) determines the direction of spread and the strength of the fire. In his research, Stoyanov (2021) found that the largest share of forest fires, on the territory of the Territorial Division of State Forestry "Botevgrad", caused by the burning of pastures and stubble (67.6%), i.e. from improperly performed agricultural activities and non-compliance with fire protection requirements. According to the established National Methodology (MAF), with a fire risk value of 0.172, TD of SF "Botevgrad" is a territory with an average degree of forest fire risk.

The purpose of the present study is to determine the impact of afforestation measures on the main characteristics of the soils and other components of the forest ecosystems after a fire in the forest territories of the TD of SF ''Botevgrad", which will support the planning and implementation of activities to restore forest ecosystems and increase of their productivity.

Material and methods

Description of study area

TD of SF "Botevgrad" is located in Northern Bulgaria. The State Forestry is situated on the north-eastern slopes of the Murgash section of the Western Stara Planina

Mountain, part of the north-western Etropol Balkan (part of the Middle Stara Planina Mountain), as well as the Botevgrad Predbalkan.

The topography of the State Forestry's territory is mainly mountainous. From the central ridge of Stara Planina Mountain, to the north and northeast towards Botevgrad's Plain, many steep ridges descend, dissecting the relief of the Stara Planina Mountain slopes. The Botevgrad Predbalkan has a hilly character. The main chain starts from the Pravets Pass and follows a direction from east to northwest.

The territory of the TD of SF "Botevgrad" is in the Moderate-continental climatic sub-region of the European-continental climatic region and covers two climatic regions, namely: Predbalkan (sub-mountain) climatic region and Mountain climatic region – Mid-Mountain part (Sabev, Stanev, 1963). The climate in the studied area is continental, and in the higher parts – mountainous. The average annual temperature is about 12.6°C, and the amount of precipitation – about 971 mm. The obtained values for the De Marton index (Raev et al., 2011) show that the plant communities in the area are in the zone of variation of the index from 30 to 40 and in the zone from 40 to 70, i.e. these are areas with optimal temperature and humidity conditions for tree vegetation.

According to "Forest Vegetation Zoning of Bulgaria" (Zahariev et al., 1979), the territory of TD of SF "Botevgrad" falls into the Mizian Forest Vegetation Region (M), Northern Bulgaria sub region (NB), Forest Vegetation Belt M-I – Lower Plain-Hyllus and hilly-foothill belt of oak forests (0-600 m a. s. l.) and M-II – Middle Mountain belt of beech and coniferous forests (600-1800 m a. s. l.).

Sampling

In order to take into account the changes that occurred in the values of the studied characteristics for soils, forest litter and grass cover after afforestation, (respectively 2, 3-4, 18 and 20 years as of 2021-2022), several areas after forest fires in the territory of the TD of SF "Botevgrad" were identified. Eight representative objects were selected, of which two were in Austrian pine (*Pinus nigra* Arnold) plantations (Object 3 and Object 5), one in a spruce (*Picea abies* Karst) plantation (Object 1) and one in a Scots pine (*Pinus sylvestris* L.) plantation (Object 8), created after afforestation activities in the burned territories. At the same time, in TD SF "Botevgrad", four other sites were identified, serving as control studies. (Objects 2, 4, 6 and 9). In each sample area, we made one main soil section and soil samples were taken for analysis by genetic horizons. In the Objects with plantations created after the fire, 4 soil test pits (surface cuts) were additionally made and samples were taken from layers 0-10 cm and 10-20 cm in order to verify the obtained data for the soils in the experimental areas. The forest litter was sampled (25/25 cm) in three replicates for the Objects on gray forest soils (Gray Luvisols) (5th and 6th) and for the Objects on brown forest (Cambisols) unsaturated soils (8th and 9th). In laboratory conditions, the collected mass was transferred, weighed and dried at 105° C to absolute dry weight. Average dry weight, from the three replicates, is recalculated per one m2 and the amount/mass of forest litter is present as g/m2 absolute dry weight. The samples from the grass cover are taken with a template (25/25 cm) in five replicates for Objects 1, 3 and 5 and they are

Table 1. Characteristics of the sites in the researched area from the Territorial Division of State Forestry „Botevgrad “.

Object No. department/ subdivision	Alti-tude, m	Slope, degree	Characteristic of object before the fire/Characteristic of control object			Fullness	Slope expo-sure	Fire, year	Afforestation: tree species, year
			Wood composition	Age, years	Credit worthi-ness				
Object 1 237 i	1150	24^0	Scots pine7, Beech2, Birch1	40	II		West/ Northwest	Fire 2015	Spruce2018-2019
Object 2 Control 237 t	1064	32^0	Beech10 single hornbeam	105	II	0.7	Southwest/ West		
Object 3 90 a1	400	23^0	Austrian pine3, Birch1 single Hungarian oak	25	III		South	Fire 2018-2019	Austrian pine 2020
Object 4 Control 90 a1	400	23^0	Austrian pine3, Birch1, single Hungarian oak	25	III		South/ Southwest		
Object 5 232 k	350	7^0	Austrian pine10, single Birch, Hungarian oak, Coast Douglas-fir	40	II		Northwest	Fire 2000-2001	Austrian pine 2002
Object 6 Control 232 k	350	7^0	Austrian pine10, single Birch, Hungarian oak, Coast Douglas-fir	40	II	0.7	Southwest/ West		
Object 8 433 j	800	26^0	Beech10	65	IV		Northwest	Fire 2002-2003	Scots pine 2004
Object 9 Control 433 k1	750	29^0	Beech10	85	II	0.6	Northwest		

processed and presented in the same way as the dead forest litter. The main indicators characterizing the sample Objects are presented in Table 1.

Characteristics of experimental objects and soils

Soil types and species are determined according to the Basic Classification of Soils in Bulgaria from 1992 (Penkov et al., 1992) and the International Reference Base (WRB, 2014). Representatives of three soil classes were found in the studied area.

On soils of the class Metamorphic (Cambisols), with a representative soil type of brown forest soils (Dystric-Eutric Cambisols) are situated Object 1 – Spruce (*Picea abies* Karst) plantation and Object 2 – control, as well as Object 8 – Scots pine (*Pinus sylvestris* L.) plantation and Object 9 – control. In the first case, at Objects 1 and 2, the brown forest soils, of the Eutric Cambisols type, formed in the upper part of the slope on sedimentary rocks, fused (solidified) mechanical sediments, including conglomerates and sandstones. In the second case, at Objects 8 and 9, the brown forest soils, of the Dystric Cambisols type, formed in the upper part of the slope on metamorphic rocks represented by the quartzites obtained from the deep metamorphism of the sandstones (Donov et al., 1974). These are typical beech habitats, prevailing on steep to very steep slopes (from 24° to 32°) in the range from 700 m to 1200 m a. s. l., mostly on western exposures with a northern or southern component (Table 1).

The control plantations, in both cases, are mature beech stands, between 85 and 105 years old, of site class (bonitet) II at fullness 0.6-0.7. The spruce plantation (Object 1) is very young, only 3-4 years old, established in 2018-2019 with 3-year-old saplings (after a fire in November 2015), with an interception rate of 89% in 2018, 90% in 2019 and cultivated in 2020. The Scots pine *(Pinus sylvestris* L.) plantation (Object 8) is much older, more than 18 years old, reforested in 2004 (after a fire in 2002-2003), with an undergrowth of beech, a single Sessile oak (*Quercus petraea*) and Scots pine *(Pinus sylvestris* L.). Both plantations, of Spruce and Scots pine, are created after afforestation with three-year saplings and preliminary soil preparation in terraces on steep terrains.

Object 3 – Austrian pine (*Pinus nigra* Arnold) plantation and Object 4 – control are spread over soils of the class Pseudopodzolis (Planosols), represented by a single soil type that bears the same name. In the past, according to the 1980 classification, these were the soils with the old name "light gray" forest soils. Planosols in the area are formed on acidic massive rocks, including Old Mountain quartz porphyries, a paleovolcanic analogue of the granite, or granodiorites, which also represent a transition to the granites (Donov et al., 1974). Both Objects, before the fire, represented plantations of Austrian pine, mixed only with Birch (*Betula alba* L.) and Hungarian oak (*Quercus frainetto* Ten.), under the ridge of steep slopes up to 23° at 400 m a. s. l., mostly on southern exposures, rarely with a western component (Table 1). The control stand is a young, 25-year-old plantation of site class (bonitet) III, composed mainly of Austrian pine, a few Birches and Hungarian oaks. The newly established Austrian pine plantation is very young, reforested in the spring of 2020 with three-year-old saplings (after fire in 2018-2019).

Object 5 – Austrian pine plantation and Object 6 – control are situated over soils of the class Luvisols, with a representative soil type of gray forest soils (Grey Luvisols). The Luvisols in the area are formed on massive rocks, including Old Mountain granodiorites, which represent a transition to the granites. These are moderately acidic intrusive rocks formed by the solidification of magma below the earth's surface, containing mainly the minerals quartz and orthoclase (Donov et al., 1974). Both Objects, prior to the fire, were approximately 40-year stands of Scots pine, singly intermixed with Birch, Hungarian oak, and green Douglas fir (*Pseudotsuga douglasii* (Lindl.) Carrière), on gentle slopes of 7°, in the lower part of the slope at 350 m a.s.l. The control, Object 6, is a 0.6 completeness plantation located on a west/southwest-facing slope, and the plantation, established on the burned area, is located on a northwest-facing slope. The Austrian pine plantation, afforested in 2004 with three-year-old saplings (after a fire in 2000-2001), is over 20 years older.

Methods

In the assessment of soil indicators and soil degradation, modern methods for field and laboratory studies are applied to study soil differences in the area (Donov et al., 1974; Donov, 1993). The main water-physical characteristics of soils define as follows: bulk density (according to Kaczynski in an undisturbed state with a cylinder), relative density (by the pycnometric method), porosity (according to the calculation method), soil (momentary) moisture (by the thermostatic method), skeleton content (>1mm and >3mm by weight method) and mechanical composition (according to Kaczynski's pipette method). Soil aggregates, with their number, size, and water resistance, affect the size and distribution of soil pores, moisture, and overall soil resistance to erosion (Hamblin, 1986).

The availability of biogenic elements in soils, forest litter and grass cover were determined by the concentrations of carbon and total nitrogen. The carbon/nitrogen ratio in soils was calculated using the formula C: N = (% C: % N) x 1.17 based on atomic ratios (Orlov, Grishina, 1981). The stocks of organic carbon and total nitrogen in soils were determined, based on data from measurements of their content. The acidity in aqueous extract (pH in H_2O) of all samples was determined potentiometrically (according to standard ISO 10390:2005(E).

All chemical and physical analyses were carried out according to accepted and approved methods in the research and specialized laboratories of the Forest Institute at the BAS, Sofia.

Results and Discussion

Soils

The consequences of forest fires last for decades, and under our climatic conditions, they usually lead to negative impacts in terms of the productivity of ecosystems, including tree stands (Tashev et al., 2003; Velizarova, 2014a). Assessment of the state of the soil

Table 2. Hydro-physical properties of soils by sites in the studied area

Object/ horizon, cm	Soil moisture, %	Bulk density, g/cm³	Relative density	Porosity, %	Coarse fragments, (>3mm), %	Coarse fragments, (>1mm), %	Mechanical composition, %		Fraction <0,001mm, %
							clay (<0,01mm)	sand (>0,01mm)	
1. Ah 0-13	12.35	1.23	2.5	51	49.18	12.03	42.47	57.53	-
B1 13-43	16.27	1.05	2.9	64	44.65	13.17	38.21	61.79	8.28
B2 43-70	17.03	1.20	2.6	54	48.35	14.95	33.48	66.52	4.09
2. Ah *0-9*	*16.74*	*1.29*	*2.7*	*65*	*49.71*	*15.94*	*42.73*	*57.27*	4.16
B1 9-35	*17.02*	*1.14*	*2.3*	*51*	*57.37*	*13.39*	*43.87*	*56.13*	4.16
B2 35-52	*20.67*	*1.11*	*2.6*	*57*	*27.59*	*16.32*	*42.79*	*57.21*	12.46
B3 52-78	*14.11*	*1.33*	*3.0*	*56*	*27.02*	*15.63*	*43.17*	*56.83*	4.17
3. Ah 0-12	2.49	1.43	0.9	57	16.23	20.57	16.61	83.39	4.08
B1 12-33	3.70	1.31	1.5	15	33.84	20.59	13.15	86.85	4.08
B2C 33-53	4.21	-	1.1	-	37.27	28.65	13.78	86.22	4.1
4. Ah *0-13*	*3.48*	*1.55*	*2.0*	*22*	*37.05*	*18.97*	*20.64*	*79.36*	4.01
B1 13-38	*3.00*	*1.53*	2.5	*39*	*41.22*	*19.96*	*16.53*	*83.47*	-
BC 38-56	*3.34*	-	2.6	-	*29.34*	*22.87*	*25.88*	*74.12*	8.07
5. Ah 0-6	1.26	1.44	2.7	47	66.95	15.14	16.15	83.85	12.11
BC 6-24↓	2.28	1.43	2.2	35	91.04	9.32	12.37	87.63	4.06
6. *A 0-12*	*1.76*	*1.36*	2.3	*41*	*38.81*	*25.09*	*20.32*	*79.68*	-
BC 12-40↓	*3.10*	*1.42*	2.4	*41*	*79.67*	*5.55*	*20.40*	*79.60*	4.04
8. Ah 0-10	2.25	0.98	2.9	66	-	-	41.19	58.81	16.31
BC 10-45	3.01	1.03	2.7	62	-	-	45.40	54.60	12.27
C 45-50↓	2.42	-	2.8	-	-	-	36.70	63.30	4.08
9. Ah *0-4*	*2.07*	*0.87*	2.2	*60*	-	-	*42.85*	*57.15*	20.6
BC 4-40↓	*3.34*	*1.06*	2.0	*47*	-	-	*40.68*	*59.32*	16.31

surface affected by fire is important for predicting the duration of the recovery period of the hydrological and biogeochemical cycle after it. Fires cause changes in the physical, chemical and biological properties of soils and other components of forest ecosystems. Data from Table 2 shows the main physical characteristics of the soils by objects of the three soil classes indicated (according to World Reference Base for Soil Resources, 2014).

The changes in the **physical properties of soils** under the influence of forest fires are expressed mainly in the redistribution of the fractions of the mechanical composition, which leads to an increase in the susceptibility of the fire-affected soils to erosion. The differences found are due to both the influence of tree species and the type of fire (Velizarova et al., 2010). With a predominance of sand fractions consisting mainly of primary minerals, the ability of the soil to retain moisture and nutrients is lower. Their smaller total surface and the larger pores formed between the soils particles is the cause for this. The predominance of the clay fraction (<0.001 mm) leads to an increase in the capacity of the soil to retain moisture and nutrients (Osman, 2013). The fractions of the mechanical composition change in the fire process depending on the temperature change. The temperature reached during the fire depends on many factors such as the type and amount of plant waste on the soil surface, humidity, wind, slope, etc.

Brown forest soils (Cambisols) in the area, saturated or unsaturated, affected or unaffected by fire, as a genetic feature, have a higher content of clay fraction (<0.01 mm) along the profile, compared to pseudopodzolic and gray forest (Gray Luvisols) soils (Table 2). A similar trend is observed in the data on the clay content in the soil test pit (surface soil layers) (Table 3).

Table 3. Water-physical properties of soil test pits (average values)

Object No	Layer, cm	Soil moisture, %	Relative density	Hygroscopic humidity %	Skeleton >3 mm %	Skeleton >1 mm %	Mechanical composition, %		Fraction <0,001mm, %
							clay	sand	
Object 1	0-10	22.54	2.7	3.96	47.67	22.09	37.32	62.68	6.23
	10-20	20.37	2.5	3.72	41.18	17.13	38.38	61.87	6.24
Object 3	0-10	2.19	2.3	0.94	23.47	24.06	11.13	88.87	5.39
	10-20	3.42	2.4	1.04	26.24	18.81	15.18	84.82	5.40
Object 5	0-10	2.22	2.5	1.37	19.33	23.72	19.62	80.38	4.06
	10-20	5.72	2.5	1.37	39.97	22.11	12.60	87.40	4.06
Object 8	0-10	3.15	2.5	2.15	-	-	25.11	74.90	9.10
	10-20	2.53	2.6	3.51	-	-	41.41	58.59	13.84

For the most part, in terms of mechanical composition, these soils are medium sandy clay (clay content between 30 and 45%). Although insignificant, the amount of clay fraction of the soils in Object 8, in an old beech stand (18 years after the fire), was higher (36-45%), in contrast to the soils in the recently burned areas of Object 1 (33 -42%). The soil test pit data (Table 3) confirm that the brown forest soils, under the older stands of Scots pine, contain higher amounts of fraction < 0,001 mm. Like this trend, Velizarova et al. (2002) indicated that soils affected by fire under conifer crops (in this case the burnt Scots pine plantation at Object 1), experienced more significant changes in their structural-aggregate composition, compared to those under deciduous forests (in this case the burnt beech stand at Object 8). An increase in the quantity of clay fraction is also found in a study of brown forest and cinnamon forest soils affected by fire in the regions of Plana Planina and Ihtimanska Sredna Gora (Velizarova, 2011). It is likely that the temperature reached during a fire in broadleaf vegetation is lower than that in conifers, due to the different chemical composition of leaves/conifers and stand bark (Petrin et al., 2014).

The soils in the burned Spruce-forested area (Object 1), 3-4 years after the fire, contain higher amounts of the sandy fraction, varying between 57 and 67%, which according to some authors (Velizarova et al., 2001a) is due to the destruction of the fractions of the large skeleton (>3 mm). Mangas et al. (1992) found similar results in the change of fractions of mechanical composition in the soil, immediately after a forest fire. In the control (Object 2), the amount of sandy fraction remained stable along the profile (between 56-57%). Under the newly established Scots pine plantation (Object 8), more than 18 years after the fire, the soils contained a reduced amount of sand fraction (54- 63%), but still higher than that in brown forest soils from the control 9th Object (Table 2). The present study shows that even 18 years later, the above-mentioned trend regarding the redistribution of mechanical fractions is maintained. It has been establishedthat forest fires increase the susceptibility of soils to erosion, which is primarily due to the redistribution of the fractions of the mechanical composition with a tendency to increase the fractions of sand (Velizarova et al., 2010).

On the surface of the soil, on steep to very steep slopes, in the burned area of Object 1, field surveys showed a massive presence of large flat stones and larger tree roots left after the cutting of the burned wood. The lack of the fine soil in some places, and the inflicted flat or angular stones and gravel are both proof of an ongoing erosion process.

In terms of skeletal content (particles >1 mm), brown forest soils in the region above 1000 m a.s.l. (Objects 1 and 2) are several times richer in the large skeletal fraction (>3 mm), both in the burned area, confirmed by the results for the soil test pit (Table 3), and in the control (Table 2). A similar trend was found by Velizarova et al. (2002) and by Bogdanov (2012) for fire-affected soils in Scots pine plantations.

Of the other water-physical characteristics of the brown forest soils, the change in soil moisture stands out (Table 2). The percentage of soil moisture on the profile, at both Objects above 1000 meters above sea level, is significantly higher, due to

the influence of climatic elements (temperature and precipitation), specific to the studied area of the TD of SF Botevgrad, confirmed and from our previous research (Stoyanov, 2021). The soil moisture of the samples from the soil test pit in Object 1 has the same trend (Table 3). The testing of the profiles in the area, carried out after the rain, has an additional impact. The soils in this zone are heavier, with an increased content of the clay mechanical fraction (<0.01 mm), which in turn leads to an increase in the capacity of the soil to retain more moisture (up to 20-22%). Because of the heavier mechanical composition, these soils are denser, with a bulk density above 1.3, with a relative density that can reach values of 2.9-3.0, due to their formation on hardened sedimentary mechanical deposits and the relatively lower porosity due to the reduction of the volume of pores between the soil particles (table 2). The brown forest unsaturated soils, in the range of 700-800 m a. s. l. (Objects 8 and 9), after an 18-year recovery period, are slightly clayey, and show a low soil moisture retention capacity (no more than 3%). This is also confirmed for the soil test pit (Table 3), at a reduced (often below 1.0) bulk density and smaller total surface area due to larger pores forming between soil particles.

The pseudopodzolic soils (Planosols) in the area, in terms of the distribution of the mechanical fractions (Table 2), define as slightly sandy-clay in the control Object 4 (clay fraction between 20 and 30%) and clay-sandy in the recently burned Object 3 (clay fraction between 10 and 20%). Such a ratio of the clay fraction confirms the conclusion made above for the brown forest soils that the soils in the burned area (Object 3) forested with Austrian pine soon after the fire (in 2018-2019) contain higher amounts of the sandy fraction (between 83 and 86 %), primarily due to the destruction of large skeletal particles (>3 mm). This feature is also confirmed by the high amounts of sandy fraction in the soil test pit (Table 3). In similar cases, Mataix-Solera, Cerdà (2009) and Velizarova (2014a) indicate that forest fires lead to the destruction of soil structure, by destroying the stability of aggregates and increasing the susceptibility of soils to erosion. Because of the fire, the percentage content of the smaller skeletal fraction (particles >1 mm) in the Planosols profile from the burned area and in the soil test soil test pit was higher (over 20%) compared to the control variant (Object 4). The soils from this Object, after the fire, have very low relative density values (between 0.9-1.5), directly related to the mineral composition of the soil-forming rocks in place. The places for the formation of these soils are steep slopes, with a slope of more than 20° and exposed exposures (south and southwest). These are dense soils, judging by the volume density values, with reduced porosity (no more than 57%), with deteriorated water-air regimes and a significant influence on the physico-chemical and biological processes occurring along the soil profile. A genetic feature of Planosols is their very low natural fertility.

The gray forest soils, distributed in the lower sloping parts of sunny (southwest/west) or shady (northwest) slopes in the Predbalkan, in the zone with a moderate-continental climate (annual amount of precipitation 580-700 mm and average annual temperature 10-11°C), exhibit some of their provincial characteristics. Regardless of their location, these soils have a shallow profile of the A/BC type, undivided and

undifferentiated in terms of mechanical composition, and the vegetation formed on them is made up of artificially created 40-year Austrian pine plantations with a uniform structure (Regulation No. 2 of 02.7.2013). The small size and thinner bark of trees in young conifers are also a prerequisite for their higher death rate because of fire (Stankova et al., 2020). The distribution of mechanical fractions in gray forest soils after a fire resembles that of Planosols, but for different periods (Table 2). In Object 5, after 20 years of restoration, the percentage content of the sand fraction (>0.01 mm), both along the profile and at the soil test soil test pit, has increased to 83-87% (Table 3). Regarding the clay fraction (<0.01 mm), the soils in the burned Object 5 belong to the loamy-sandy category (clay content between 10 and 20%), also confirmed by the data of the pits, and the soils of the control 6 – to slightly sandy-clay (clay content between 20 and 30%). On the profile of the gray forest soils from the area, an increased participation of the larger skeletal particles (those >3 mm) is observed, which reaches quite high values in the burned area (66-91%). In this case, we have enhanced the influence of soil formation factors, especially the relief (concave part at the foot of the slope) and the bedrock (of hard rocks and the products of their weathering), observing the transfer of the weathering products and their accumulation along the profile. Shallow gray forest soils often form under such conditions. The values for the volume density of the gray forest soils at both Objects (after fire and the control) are slightly below the average for the country (1.5 g/cm^3), and the total soil porosity hardly changes along the profile (Table 2).

The results for **soil acidity** do not show great differences in the changes caused by fires (Table 4).

Moreover, other authors (Simard et al., 2001) found that soil pH values did not change after fire, despite an increase in forest litter values. In our studies, this is observed for Object 5 after a fire (Table 4). The increase in soil pH after a fire is usually short-term and depends on the initial soil pH values, the amount of ash accumulated from burning the forest floor, the chemical composition of the ash, and soil moisture (Molla, 2017). In addition, the temperature reached during the combustion process can have a different effect on soil pH. Fernandez et al., (1997) found a decrease in soil pH as lower temperatures reached during fire and an increase in soil pH as higher temperatures reached. The decrease in pH values (acidification) in brown forest soil (Object 1), for 3-4 years after the fire (from 2018-2019), compared to the control option (Object 2), is weak and is probably due to leaching/carrying out the dissolved compounds in the lower layers. There was a certain increase in the pH values in the pseudopodzolic soils for 2 years after the fire (Object 3), also confirmed by the data on the layers of the soil test soil test pit in this Object (Table 5), compared to the control variant (Object 4).

For the deeper soil's horizons, the trend is the same (Table 4). Bogdanov (2013), one year after the impact of a forest fire, also found a similar change in pH values under an Austrian pine plantation. Said (2008) hypothesizes that the impact of forest fires on soil acidity is less in sandy soils than in soils with a higher clay fraction.

Table 4. Chemical properties of soils by Objects in the studied area

Object №	Horizon. cm	Organic C %	Total N %	pH H_2O	Stock C t/ha	Stock N t/ha	C: N	C: N (Orlov, Grishina, 1981)
Object 1	Ah 0-13	6.316	0.129	3.42	80.82	1.65	49	57
	B1 13-43	2.526	0.110	3.81	68.83	3.01	23	27
	B2 43-70	1.263	0.070	4.02	34.81	1.94	18	21
Object 2	Ah 0-9	3.789	0.115	4.56	37.11	1.12	33	39
	B1 9-35	3.158	0.107	4.88	80.78	2.74	29	34
	B2 35-52	2.632	0.079	4.70	41.52	1.24	33	39
	B3 52-78	1.579	0.061	6.51	45.99	1.79	26	30
Object 3	Ah 0-12	2.526	0.074	5.49	34.38	1.01	34	40
	B1 12-33	1.789	0.055	5.35	39.06	1.19	33	38
	B2C 33-53	0.526	0.015	5.29	-	-	34	40
Object 4	Ah 0-13	4.347	0.137	5.26	71.07	2.24	32	37
	B1 13-38	2.000	0.074	4.88	61.39	2.26	27	32
	BC 38-56	1.263	0.064	4.45	-	-	20	23
Object 5	Ah 0-6	0.999	0.069	5.13	7.30	0.51	14	17
	BC 6-24↓	0.500	0.038	4.44	11.62	0.89	13	15
Object 6	A 0-12	0.799	0.045	4.51	9.77	0.55	18	21
	BC 12-40↓	0.599	0.038	4.28	22.52	1.44	16	18
Object 8	Ah 0-10	4.995	0.084	3.91	-	-	59	69
	BC 10-45	2.098	0.069	4.51	-	-	31	36
	C 45-50↓	1.499	0.061	4.08	-	-	25	29
Object 9	Ah 0-4	4.424	0.084	3.58	-	-	52	61
	BC 4-40↓	3.095	0.068	3.77	-	-	45	53

Table 5. Chemical indicators of soil test pits (average values)

Object, №	Layer, cm	Organic C %	Total N %	pH (H_2O)	C: N	C: N (Orlov, Grishina, 1981)
Object 1	0-10	5.5262	0.2083	4.11	34	39
	10-20	3.2104	0.1305	4.17	29	34
Object 3	0-10	2.6052	0.0494	5.48	38	45
	10-20	1.6240	0.0322	5.27	41	48
Object 5	0-10	1.2611	0.0743	4.39	23	27
	10-20	0.8991	0.0781	4.47	14	16
Object 8	0-10	4.0672	0.0866	3.79	49	57
	10-20	2.6862	0.0735	3.70	42	49

Differences in the pH values, both in the gray forest soils and in the brown forest soils, unsaturated, after a long period of the fire (18-20 years), are not noted (Table 4).

Some authors (Velizarova, 2014a; 2014b) compare the impact of fires on organic matter with the processes of biological transformation of plant residues and/or molecular restructuring because of enzymatic reactions or abiotic processes, which in natural conditions take place over hundreds or thousands of years. Table 4 features **soil carbon stocks** and their changes. The highest content of organic C or soil organic matter (SOM) was found in the surface horizons of brown forest soils, saturated, from the burned spruce forested area (Object 1), respectively 6.316%, for several years after the fire (November 2015). This tendency in the change of the carbon content is preserved in the soil test pits (Table 5). The amount of carbon is higher than the determined content of organic C in the soils of the control variant (Object 2), respectively 3.789%. In depth along the profile, the amount of organic matter decreases twice. One of the possible reasons for the higher carbon presence in the surface soil layer, immediately after a fire, is the burning and charring of plant residues from the stand assembly and from the forest litter, some of which penetrates the soil mineral layer (González-Pérez et al., 2004; Certini et al., 2011). Before the fire, there were 40-year-old Scots pine plantations of site class (bonitet) II, established on a beech stand with a northern component. The amount of carbon in the surface layers of the brown forest soils, unsaturated, under the Scots pine crop (Object 8), 18 years after the fire (2002-2003) was 4.995%, respectively. This amount is very close to the established carbon content in the surface horizons of the soil from the control (Object 9), respectively 4.424%, most likely due to a relative equilibrium reached in the soil (Table 4). The reason can be the stabilization of carbon in the soil after the impact of the fire, and more specifically the physico-chemical stabilization, through its sorption on the clay minerals (Goh, 2004; Hurteau, Brooks, 2011). The data on the variation of the mechanical composition fractions mentioned above show a relatively good presence of the clay fraction (particles <0.01 mm) along the profile of these soils (Table 2), which indirectly confirms this probable mechanism

of carbon stabilization in the soil after a fire. Stable complexes between clay minerals and humus substances in the soil determine the stability of the soil aggregates and prevent the development of degradation processes.

In the gray forest soil, under an Austrian pine plantation, afforested nearly 20 years ago (Object 5), a similar trend is observed in the change of carbon content after a fire. It reaches values close to those found in the control variants (0.799-0599%) just like in the soil under a Scots pine plantation (Object 8), but against the background of the overall very low carbon content of the profile (Table 4). Soil organic matter content has been shown to be a key factor in the stability of soil aggregates, and therefore in the resistance of the soil structure to destruction by fire (Oades, 1993).

In the surface horizon of pseudopodzolic soils under Austrian pine plantation (Object 3), soon after fire (2018-2019), the organic carbon content decreased twice (2.526%) compared to the control variants (4.347%). The different effects that fires have on the concentration of soil organic carbon in soils by several factors, including the genesis of the soils (Velizarova, 2014a).

Most of the **total nitrogen** in the soil is unavailable to plants. Under the action of microorganisms, during the processes of nitrification and ammonification, complex organic compounds containing nitrogen mineralize, which convert into forms digestible by plants. Nitrogen constitutes 1/12-1/20 part of soil organic carbon; therefore the nitrogen content of the soil is closely related to that of carbon. This explains trends in changes in amounts of total nitrogen under the action of fires, their impact, and the time required for recovery after afforestation. These changes follow exactly and in parallel the changes in the amounts of carbon in the different soil types and are in very low amounts (Table 4). Therefore, the conclusions drawn regarding changes in soil carbon are, in our case, also valid for quantitative changes in nitrogen.

The C: N ratio, i.e. the amount of carbon to the amount of total nitrogen in the soil expresses the degree of decomposition of organic substances and is an essential indicator for clarifying the processes in the soil (Donov et al., 1974). The faster the organic matter decomposes, the lower the amount of carbon and the higher the amount of total nitrogen. This ratio is an indirect indicator of the degree of humification of organic substances and allows, in a comparative mode, to judge the progress of humification processes in the soil, as well as the enrichment of organic substances with nitrogen. In calculating this ratio, percentages by weight are usually used. Some authors (Orlov, Grishina, 1981) use atomic rather than percentage ratios, since atomic ratios allow for improvement of the features in the structural characteristics of substances.

Most of the soils in the area, at this stage of the study, were determined to be low in nitrogen enrichment as C: N >20, both for percent and atomic ratios. In brown forest soils, unsaturated, under an older Scots pine plantation on steep, north-facing slopes (Object 8) and a mature beech stand at the same location (control 9), a ratio of C:N>40 indicates a delayed transformation of soil organic matter (table 4). For the values of the C: N ratio from the plots in these soils a similar tendency is observed (Table 5). Exceptions are present in the gray forest soils, where for the substrates in the burned area of Object 5 we have a medium (at C: N between 12 and 16) and for

the control (Object 6) we have a low (at C: N between 16 and 20) degree of enriching the soil with nitrogen.

In other studies (DeLuca, Aplet, 2008) an increase in these values has also been found.

Soil carbon stocks and their changes are presented in Table 4. The data show that the fire in the old Scots pine stands on saturated brown forest soils (Object 1) most strongly affected the carbon stocks in the top 13 cm layer of the soil. From 37.11 t C ha-1 in the control variant (Object 2), the carbon stocks increased more than 2 times – to 80.82 t C ha-1 only 3-4 years after the fire. In other studies (DeLuca, Aplet, 2008) an increase in these values has also been found. Some authors believe that the main reason for this is the deposition of carbonized plant residues from the forest litter and biomass affected by the fire and stabilization of carbon in the surface layer (Certini et al., 2011; Inbar et al., 2014). In dynamics, the tendency is towards equalization of the carbon stocks, in depth along the profile, in the fire-affected soils with those of the control variants (Table 4).

Fire affecting the original 25-year Austrian pine plantation on Planosols (Object 3) caused a permanent reduction in carbon stocks to a depth of 30–40 cm, compared to the control option (Object 4). This reduction is characteristic of the entire period after the afforestation of the new, post-fire, Austrian pine plantation. Other authors, when studying soils under coniferous forests affected by forest fire (Velizarova et al., 2001b; Velizarova et al., 2014b) found a similar phenomenon. In this case, carbon stock losses in fire-affected soils were double that of the control options. Obviously, due to the higher skeleton (particles over 1 mm) and density of the soil from this Object, carbon stocks decrease (Table 4).

A similar trend in changes in carbon stocks in Austrian pine plantations established on gray forest soils (Object 4 and Object 5) is observed. The difference is that here the plantation is more than 20 years old, and the recovery processes that took place in the area after the fire have erased the large differences in terms of carbon stocks and almost equalized them (Table 4).

Since the nitrogen content of the soil is closely dependent on that of organic carbon, changes in **total nitrogen stocks** follow the changes in carbon stocks in different soil types (Table 4). In general, they are in very low amounts and show the same trends. Therefore, the inferences made regarding changes in carbon stocks are, in our case, also valid for quantitative changes in total nitrogen stocks.

Dead forest litter

Table 6 shows the results for dead forest litter, obtained for the different indicators. The sampling was done in the stands of Austrian and Scots pine, over 18-20 years after fire (Object 5 and Object 8), as well as in the Objects serving control trials (Object 6 and Object 9) spread over gray forest soils and brown forest soils, unsaturated. The average values for each of the studied parameters are given weight mass, organic C, total N, pH (H_2O), C: N ratio and litter stock in t/ha, as well as the limits in which they change.

Table 6. Forest litter indicators

Object No	Mass, g/m^2	Organic C, %	Total N, %	pH (H_2O)	C: N	Stock, t/ha
Object 5	**1175**	**48.89**	**1.02**	**4.83**	**48**	**12.56**
	(573-1940)	(48.22-49.90)	(0.98-1.09)	(4.65-5.06)	(46-49)	(5.73-19.40)
Object 6 Control	**2370**	**50.35**	**1.04**	**4.50**	**49**	**23.70**
	(1376-3597)	(41.38-58.87)	(0.74-1.20)	(4.35-4.70)	(43-56)	(13.76-35.97)
Object 8	**906**	**54.43**	**1.04**	**3.93**	**55**	**9.06**
	(612-1250)	(43.29-60.56)	(0.72-1.23)	(3.89-3.96)	(50-60)	(6.12-12.50)
Object 9 *Control*	**1194**	**47.96**	**1.30**	**4.79**	**43**	**11.94**
	(1098-1345)	(45.75-49.12)	(0.84-1.55)	(4.61-5.05)	(32-55)	(10.98-13.45)

In the sample areas of Object 1 (3-4 years post-fire) and Object 3 (2 years post-fire), the dead forest litter is poorly formed or absent. The soil surface is covered with large rock, flat or angular pieces and roots from the old plantation, before the fire. In combination with the other conditions – steep slopes, sunny exposures, risk of drought, it is creating a prerequisite for the development of erosion processes, which endangers the newly planted plantations.

The formation and thickness of the forest litter in plantations depend on several factors: tree composition of the plantation, elements of the relief (exposure, slope, shape of the terrain, part of the relief), altitude, climatic factors (temperature, precipitation), etc. The forest litter in the control Object 6 of gray forest soils, under a 40-year-old Austrian pine plantation, on sloping and sunny slopes, represented by its three layers (L, F, and H), reaches a thickness of 9.5 cm regarding these factors. The accumulated mass of litter in this Object, composed of less humified plant residues, is high (2370 g/m^2), and its reserves are of the order of 23.70 t/ha (Table 6). Our results and those of other authors (Velizarova, 2014b) show that Austrian pine plantations are characterized by the largest stock of combustible materials from the forest litter. In the young, approximately 20-year-old, newly created plantations of Austrian pine, after a fire in the neighbourhood (Object 5), the thickness of the forest litter is three times smaller and does not exceed 3.5 cm. Therefore, both the mass (1175 g/m^2) and the stock (11.75 t/ha) of the litter in this Object are twice lower, compared to the control variant (Table 6). The amount of carbon in litter from the control area was slightly higher than that of the newly established plantation on the burned area (50.35% and 48.89%, respectively). The content of total nitrogen (1.02-1.04%) and the values of pH (H_2O), i.e. acidity in both areas did not differ significantly (4.50-4.83). The values for the C: N ratio are also close (48-49). These data show that the processes of recovery and development of the Austrian pine plantation in the period after the fire are favourable.

The forest litter in control Object 9, on brown forest unsaturated soils, under a beech plantation of various ages over 90 years old, in the middle part of steep and shady slopes, is represented by its three layers (L, F, H) and reaches up to 4 cm thick. The accumulated mass of litter in the Object is not high – 1194 g/m^2, but the degree of

humification is higher, and its reserves are comparable to 11.94 t/ha (Table 6). In the young, about 18-year-old, newly created in 2004 Scots pine plantation, after a forest fire (Object 8), the thickness of the forest litter is twice as small and does not exceed 2 cm. Therefore, both the mass (906 g/m^2) and the stock (9.06 t/ha) of litter in this Object are lower (Table 6). The percentage of carbon in the litter under beech, from the control variant, is slightly lower than the percentage of carbon in the litter under the Scots pine plantation created after fire (47.96% and 54.43%, respectively). The forest litter under the beech stand contains 1.30% total nitrogen. In contrast to the control (Object 9), the litter in the Scots pine plantation on the burned area (Object 8) was poorer in total nitrogen (1.04%). This fact is also confirmed by the values of the C: N ratio, which are higher in the coniferous plantation (C: N – 53), from which the conclusion follows that the organic waste under the Scots pine decomposes more slowly. Due to the nature of the waste, combined with the environmental conditions, the litter in the Scots pine plantation is more acidic (pH 3.93). Taken together, data on forest litter indicators show some delay in recovery processes after fire in the Scots pine plantation.

Grass cover

The results for the grass cover in the study area, average values for indicators: weight mass, organic C, total N, pH (H_2O), stock of grass cover in t/ha, as well as the limits in which they change are given in Table 7. Grass cover samples are taken from Object 1 – 3–4-year-old spruce plantation on saturated brown forest soils, Object 3 – two-year-old Scots pine crop on pseudopodzolic soils and Object 5 – over 20-year-old Austrian pine plantation on gray forest soils.

Table 7. Grass cover indicators

Object, No	Mass, g/m^2	Organic C, %	Total N, %	pH (H_2O)	Stock, t/ha
Object 1	**883.8**	**43.398**	**0.959**	**5.45**	**8.84**
	(490-1453)	(37.791-47.547)	(0.781-1.216)	(5.24-5.67)	(4.90-14.53)
Object 3	**2091.4**	**45.529**	**1.134**	**5.45**	**20.91**
	(1011-3732)	(37.343-53.603)	(0.858-1.287)	(5.26-5.72)	(10.11-37.32)
Object 5	**124.6**	**46.288**	**0.969**	**5.37**	**1.25**
	(68-226)	(43.622-49.454)	(0.766-1.149)	(5.26-5.50)	(0.68-2.26)

The data show that in terms of accumulated (weight) mass and stock, the differences are primarily determined by the length of the post-fire period, i.e. the age of the newly created plantations, from the slope and exposure of the slope on which experimental samples are staked. At Object 1 and Object 3, plantations were established 3-4 years ago (2018-2019) and 2 years (2020), quite young, still stocked and in need of replenishment. Here, the grass cover is abundant and very diverse – mouse ears (*Hieracium pilosella* L.), gorse (*Eryngium campestre* L.), wormwood (*Artemisia*

vulgare L.), mullet (*Verbascum densiflorum*), bonito (*Cirsium arvense* L.), St. John's wort (*Hypericum perforatum* L.) etc. Many weed species also occur. Grass cover mass is highest in Object 3 (2091.4 g/m^2), on southern exposures, only 3-4 years after the fire (2018-2019), which accounts for the higher stock (20.91 t/ha). Compared to this area, at Object 1, forested with spruce, located on steep slopes, with a northern component, the weight mass of the grass cover is lower by almost two times (883.8 g/m^2), and the stock does not exceed 8.84 t/ha (Table 7). The content of biogenic elements, carbon and nitrogen, in both mentioned Objects, is mostly determined by the species composition of the grass cover, and the amounts of these elements are slightly higher at Object 3 (with more than 2% for carbon and less than 1 % for nitrogen). The acidity of the grass mass for both Objects is the same (pH- 5.45). Grass cover mass and stock at Object 5, over 20 years old Scots pine, on sloping slopes with a north component, were much lower (124.6 g/m2 and 1.25 t/ha, respectively). These values indicate that the cover has a reduced cover and species composition, with areas where it is lacking altogether (an abundance of mosses is present instead). Here you can find grass species such as milkweed (*Euphorbia cyparissias* L.), mouse ears (*Hieracium pilosella* L.), and forest sedum (*Luzula sylvatica* (Huds.) Gaudin), eyeball (*Potentilla fruticosa*) and others. In terms of carbon and nitrogen content, as well as acidity, the grass cover in Object 5 occupies an intermediate position between the previous two Objects (Table 7).

Conclusions

There is a confirmed tendency that forest fires lead to an increase in the susceptibility of soils to erosion due to the redistribution of the fractions of the mechanical composition, in which the amount of the sand fraction increases. In pseudopodzolic soils, immediately after a fire, the percentage content of the skeletal fraction (particle size >1 mm) was also increased. For a period of 20 years after afforestation, the percentage content of the sand fraction increased in the gray forest soils, due to the increased influence of the soil-forming factors relief and bedrock, followed by the transfer of weathering products. In coniferous crops on brown forest soils, after 18 years of recovery, this trend changes in favour of the clay mechanical fraction, incl. and silt particles (<0.001mm).

Changes in acidity in pseudopodzolic soils are characterized by a marked neutralizing effect of fires, compared to the control variants. No differences in pH values, both in gray forest soils and in brown forest soils, at a longer post-fire period (18-20 years) was noted.

The genetic characteristics of soils influence the differences that fires cause to the quantity and composition of soil organic carbon. In brown forest soils from the higher and wetter mountain regions, the presence of more stable complexes between clay minerals and organic substances determines the stability of soil aggregates and protects the soils from the development of degradation processes. With a longer post-fire recovery period, due to relative equilibrium reached in the soil they observe stabilization of carbon in brown forest soils, most likely due to its sorption on clay

minerals. The changes in the quantity of total nitrogen, under the influence of the fires, closely follow the changes in the quantity of carbon in the different soil types, and are in very low concentrations.

Most of the soils in the area are determined to have a low level of nitrogen enrichment, as C: N>20, both for percentage and atomic ratios.

In the first years after the fire, grass species and representatives of the Rosaceae family, *Rubus* sp., *Potentilla* sp. and others mainly carried out the restoration of the living soil cover in the studied Objects. The abundant development of grass and shrub species, after a fire, prevents the interception of forested saplings.

It's been established that Austrian pine plantations are characterized by the largest stock of combustible materials from the forest litter. The processes of recovery and development of the Austrian pine plantations in the post-fire period are favourable, but due to the nature of the waste and the environmental conditions, there is a certain delay in the recovery processes after a fire in the Scots pine plantations.

Regarding the accumulated mass and stock of the grass cover, the differences are determined primarily by the length of the post-fire period, i.e. the age of the newly created plantations, from the slope and exposure of the slope on which the test Objects are located.

Changes in forest vegetation conditions after fire, i.e. decrease in the amount of moisture, increase in illumination, extreme summer temperatures, change the main indicators of the components of plantations. The species for afforestation, which will enable the correct selection of the tree species, need to be carefully considered.

Acknowledgments

This work has been supported by the National Science Fund approved after participation in competition for financial support for projects of young scientists and postdoctoral students 'Influence of forestry activities with different intensity on main soil indicators under different tree species', financed by the National Science Fund (Contract No. KP-06-M56/1 of 11.11.2021).

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